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(56) Documents Cited
GB 2138054 A **GB 2136035 A** **US 4811801 A**

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(54) Insert stud cutter

(57) An insert stud cutter 30 comprises a tungsten carbide cylindrical body 32 with a base end and a cutter end with at least one layer 36 of ultra-hard material, polycrystalline diamond or polycrystalline cubic boron nitride, directly bonded to a surface 34 of the cutter end by a high pressure, high temperature sintering process, which surface is angled "A" with respect to an axis 33 of the cylindrical body at between 5° and 30°. The surface may be planar, convexly curved (figures 4 and 5) or a truncated cone (figures 6 and 7). At least one transition layer (41 figure 2a) may be provided between the tungsten carbide body and the layer of ultra-hard material. The ultra-hard material may comprise at least one tape cast layer.

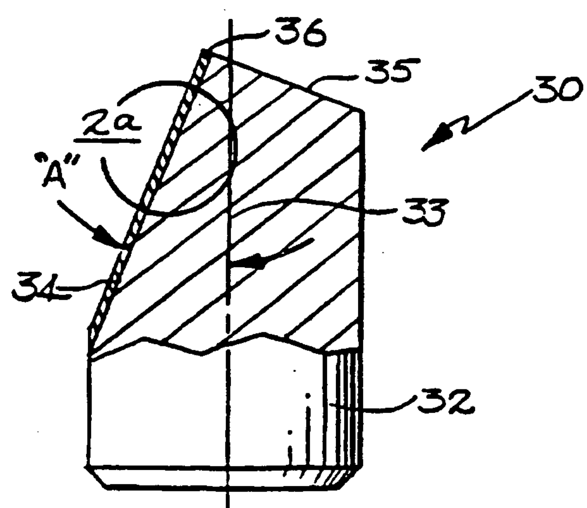

FIG. 2

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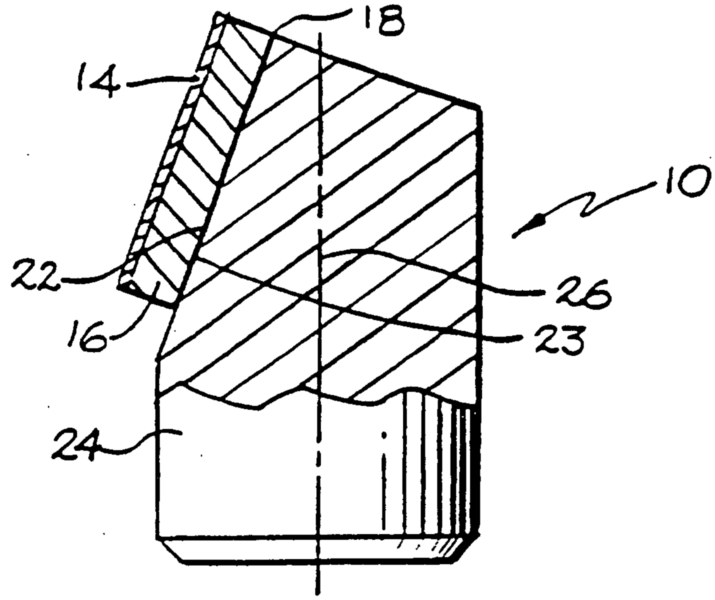


FIG. 1
PRIOR ART

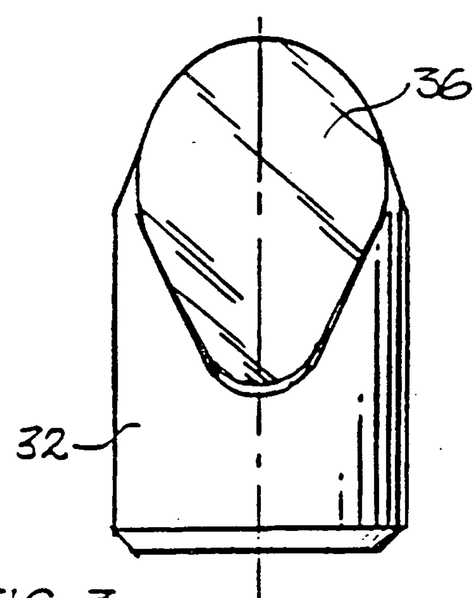


FIG. 3

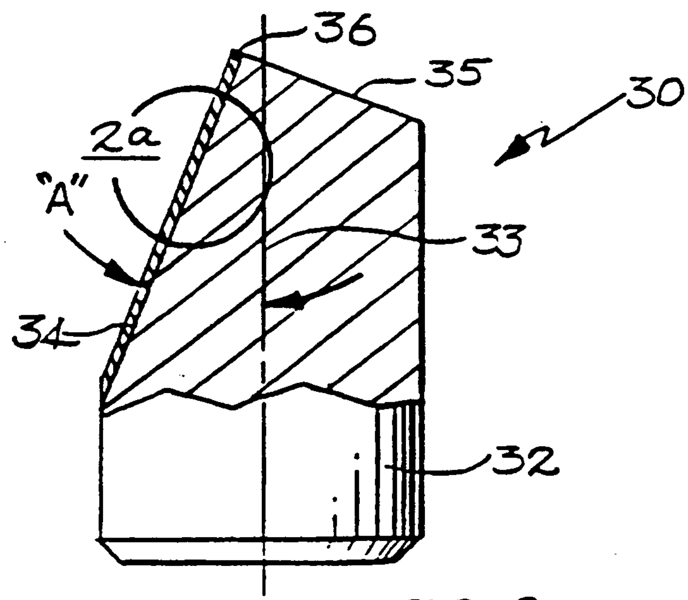
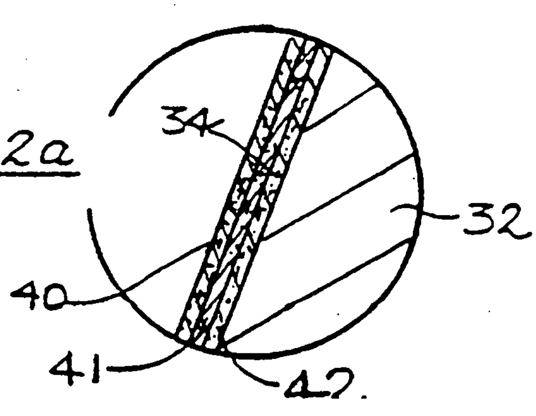


FIG. 2

FIG. 2a



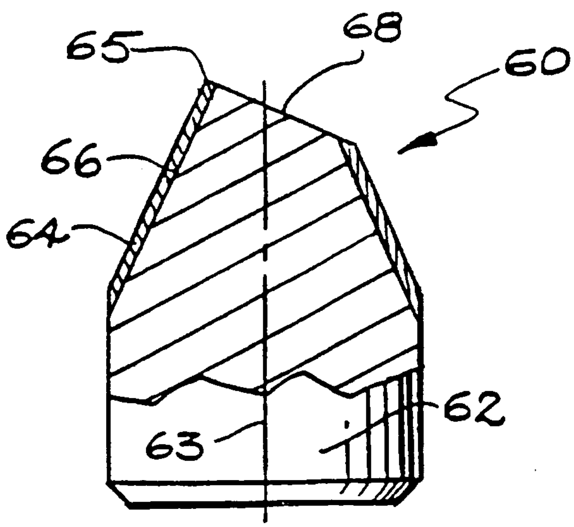


FIG. 6

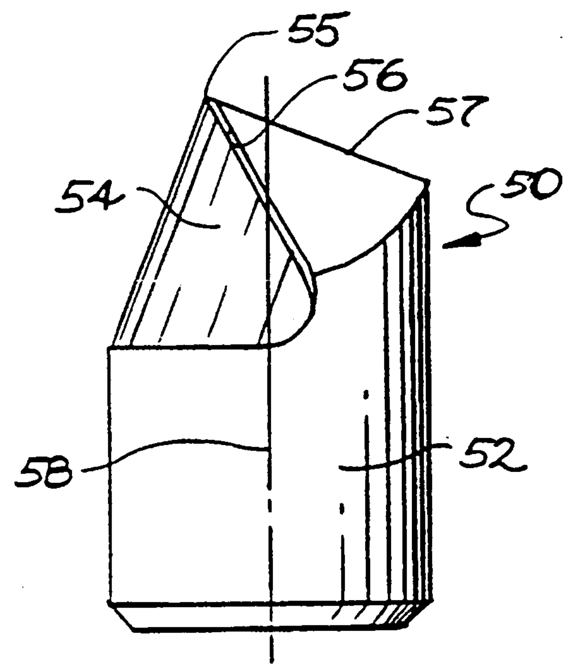


FIG. 4

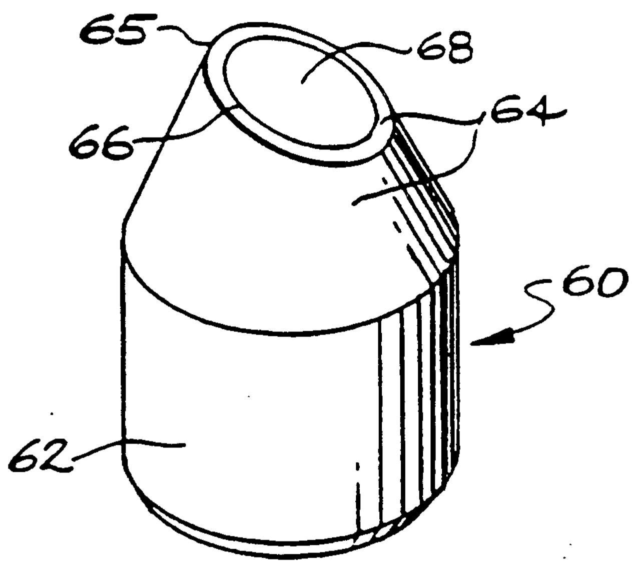


FIG. 7

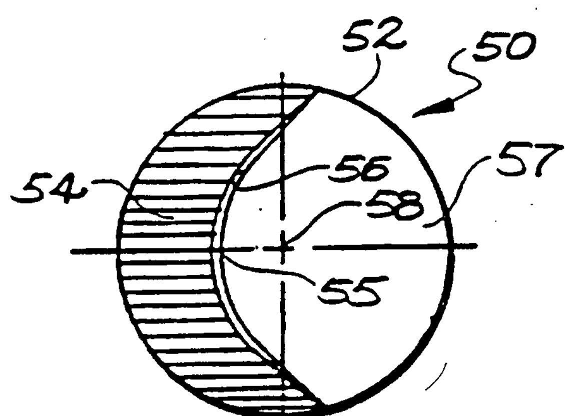


FIG. 5

INSERT STUD CUTTERS

The present invention relates to insert stud cutters. More particularly, this invention relates to diamond cutting elements for diamond drag bits.

Polycrystalline diamond compacts (PDC) have been effectively used for cutters on drag bits while drilling soft earthen formations in petroleum and mining exploration for more than a decade. The most common cutter type used in PDC drag bits is classified in the drilling industry as a "stud" type PDC. For example, a typical stud type PDC cutter is illustrated in Figure 6 and Figure 7 of U.S. Patent No. 4,776,411.

Practically all stud-type PDC cutters used to date have been manufactured as two piece units. A thin layer (approximately 0.7 to 1 mm) of polycrystalline diamond is chemically/metallurgically bonded to a face of a much thicker (approximately 4 to 5 mm) right cylinder wafer of cobalt cemented tungsten carbide. This integral diamond/carbide compact is then brazed to a cobalt cemented tungsten carbide modified cylindrical stud or post at an angle of between 15° to 20° from the axis of the stud. The top surface of the stud is typically radiused to conform to the diamond/carbide wafer cylindrical surface and relieved rearwardly normal to the diamond surface.

Although PDC stud type cutters, as currently manufactured, serve a very useful purpose, there are several disadvantages in their manufacture and application. The flat on the stud to which the PDC wafer is brazed and the carbide side of the PDC wafer must have extremely fine ground surfaces to effect a braze of necessary strength. These grinding operations are time consuming and costly.

The bonding of the PDC wafer to the carbide stud is fraught with many variables that are difficult to

control. The braze temperature is significantly higher than the thermal degradation temperature of the diamond layer and the bond interface of the diamond and carbide. Therefore, the diamond has to be protected by a complicated heat sink apparatus that is difficult to control during the braze cycle. A high reject ratio is inherent in this process, lowering output and driving up costs.

The actual braze quality is difficult to determine even with the most sophisticated non-destructive testing equipment available. An undesirable level of less than good brazes go undetected and wind up as PDC cutter failures in the field. The brazing process can also cause incipient and premature failure of the bond of the diamond layer to the carbide wafer which also will show up as a PDC cutter failure in the field. It is also difficult to braze a PDC cutter wafer that has two or more carbide particle/diamond particle transition layers that have a high cobalt level because the high differential in thermal expansion causes the PDC layer to crack during the braze cycle.

It would be desirable to provide a stud type PDC cutter that does not require a braze of a PDC wafer to a tungsten carbide stud. The new stud type PDC cutter disclosed herein eliminates the need to braze a PDC wafer to a tungsten carbide stud, thereby obviating the problems and inadequacies described above in current PDC stud design and processes.

The present invention provides an insert stud cutter for rock bits comprising: a tungsten carbide cylindrical body, said body having a first cylindrical base end and a second cutter end, said second cutter end having at least one layer of ultra-hard material selected from the group consisting of polycrystalline diamond and polycrystalline cubic boron nitride directly bonded to a

pre-formed surface on said second cutter end by a high pressure, high temperature sintering process, said pre-formed surface being angled negatively with respect to an axis of said stud body 5° to 30°.

Embodiments of the invention are described below with reference to the accompanying drawings in which:

FIGURE 1 is a partial cross-section of a prior art cylindrical stud type polycrystalline diamond compact drag bit cutter;

FIGURE 2 is a partial cross-section of an embodiment of the present invention illustrating an ultra-hard planar composite layer of polycrystalline diamond directly bonded to a flat surface formed on a cylindrical tungsten carbide stud;

FIGURE 3 is a frontal view of the stud of Figure 2 showing a polycrystalline diamond layer bonded to a flat surface formed on a cylindrical carbide stud;

FIGURE 4 is a side view of an embodiment of the present invention which is an oblique or skewed cylinder having a thin composite layer of polycrystalline diamond bonded to a curved frontal surface formed on the tungsten carbide stud;

FIGURE 5 is a top view of the stud of Figure 4 showing a curved polycrystalline diamond layer bonded to a curved frontal surface of an essentially cylindrical tungsten carbide stud;

FIGURE 6 is a partial cross-section of an embodiment of the present invention showing a cylindrical tungsten carbide stud having a truncated conical cutting end with a composite polycrystalline diamond layer bonded to the conical surface; and

FIGURE 7 is an isometric view of the stud of Figure 6 showing a diamond layer bonded to the truncated conical surface of the tungsten carbide stud.

Prior art Figure 1, a partial cross section of

an insert cutter generally designated as 10, illustrates a polycrystalline diamond stud type cutter for drag type drill bits. A thin composite cutting layer 14 of polycrystalline diamond is chemically and metallurgically bonded to a cylindrical tungsten carbide substrate 16 under high pressure/high temperature diamond synthesis conditions. Subsequently, the rearward side 23 of the substrate 16 is ground to a flat polished surface and is then attached by a high temperature braze 18 to a ground flat surface 22 on a carbide stud 24 which is formed at a rearward angle of from 15° to 20° relative to the axis 26 of the carbide stud 24. The preferred rearward angle is 20°.

Figure 2 is a partial cross section of a diamond drag bit cutter and is an embodiment of the present invention which is generally designated as 30. A cylindrical tungsten carbide stud 32 has a pre-formed flat 34 that is rearwardly inclined 5° to 30° from a stud axis 33 (angle A). The top surface 35 of stud 32 forms, for example, a radius which becomes tangent to the side edges of the flat surface 34. A thin planar composite diamond cutting layer 36 is formed on the flat surface 34 of the stud using high pressure/high temperature diamond synthesis conditions. This creates diamond to diamond bonding and bonding of the diamond composite layer to the carbide stud flat surface.

As shown in exploded view 2a of Figure 2, it is generally desirable to form, by diamond tape cast methods, a composite diamond layer 36 as a gradient of diamond and pre-cemented tungsten carbide particles. For example, an outer layer 40 comprises 90 to 100% diamond particles. A middle layer 41 comprises approximately 50% diamond and 50% carbide particles. An inner layer 42 compromises 90 to 100% carbide particles. This produces a composite diamond layer 36 with very low residual stresses coupled

with a very hard and wear resistant outer surface 40 as an integral part of a cutter having no brazed joint.

The layers are applied by the techniques and processes commonly referred to as "tape casting" in conjunction with high pressure/high temperature (HP/HT) diamond synthesis technology. Tape casting technology is commonly used in the electronics industry to fabricate ceramic coatings, substrates and multilayer structures. Tapes of various materials can be produced by a doctor blade casting process or by high shear compaction process, a proprietary process by Ragan Technologies, a division of Wallace Technical Ceramics, Inc., San Diego, California.

The two tape processes have been successfully used to produce products. Some of the basic advantages of the high shear compaction process over the doctor blade process are as follows: (1) uniform density; (2) higher green density; (3) process flexibility in controlling thickness, surface finish; and (4) higher reliability and flexibility.

Diamond layers and composites are also beneficially made by tape casting methods. Fine diamond powder is mixed with a temporary binder. The binder can be natural or synthetic high molecular weight substances such as starches, alcohols, celluloses and polymers. The diamond powder/binder mixture is milled to a homogeneous mass then rolled into strips (tapes) of the desired thickness and width, then dried to remove volatile carriers. The green tape is strong and flexible enough to be handled. The tape may be cut into the necessary shapes to conform to a tungsten carbide substrate geometry where it is temporarily glued. This assembly is then placed in a refractory metal HT/HP reaction mold and heated in a vacuum to drive off the temporary binder. The mold assembly is placed in a conventional HT/HP diamond synthesis apparatus to sinter the diamond grains together

and bond the diamond mass to the carbide substrate.

Figure 3 is a front view of the insert of Figure 2 and shows the planar composite diamond layer 36 chemically and metallurgically bonded to the pre-formed but not necessarily precision ground flat 34 of the stud.

Figure 4, another embodiment of the present invention generally designated as 50, is an oblique or skewed cemented carbide cylinder 52. A pre-formed curved frontal surface 56, which slopes rearwardly 5° to 30° in reference to stud axis 58, has a relatively thin (0.25 to 1.5 mm) non-planar polycrystalline diamond layer 54 bonded thereto under high pressure/high temperature diamond synthesis conditions. The composite diamond layer 54 is preferably fabricated by using diamond tape cast methods. This produces a cutter 50 having very low residual stresses and an ultra-hard and wear resistant cutting surface 54 without the use of an undesirable braze.

Figure 5 is a top view of the insert of Figure 4 showing a curved polycrystalline diamond surface 54 bonded to a pre-formed curved oblique surface 56 of the tungsten carbide stud. The diamond layer 54 is inclined rearwardly in relation to the stud axis 58, terminating at an apex 55. The top surface 57 of the carbide stud body is formed essentially perpendicular to the curved surface 56 and intersects the edges of the diamond layer 54. This forms a heel clearance for the diamond cutting layer while the cutter works in a borehole.

Figures 6 and 7, another embodiment of the present invention, illustrate a drag bit cutter 60 having a cylindrical tungsten carbide body 62 and a truncated conical cutting surface 64. The cylindrical cutter body 62 has a truncated conical surface 66 to which a thin layer of polycrystalline diamond 64 has been chemically and metallurgically bonded using tape casting and high pressure/high temperature diamond synthesis techniques.

This forms an integral unit with the carbide body 62. The angled surface 68 is formed by directing an EDM cut through the conical surface layer 64 about 90° to the surface. This creates the desired leading cutting edge 65 and the top trailing edge surface 68. The angled surface 68 is at an oblique angle to an axis of the cylindrical body, giving the cutting edge 65 heel clearance while drilling. The cutter so formed has very low residual stresses and requires no potentially deleterious braze. While the diamond layer 64 on the trailing conical surface of cutter 60 plays no part in the drilling action, bonding of a composite diamond layer 64 to the entire conical surface 66 before the truncation procedure simplifies the manufacturing process. It also produces superior diamond layer properties.

It should be noted that a single layer or multiple layers of diamond may be utilized in fabricating the above described embodiments to meet the needs for field application or for ease of manufacture.

An advantage of the present invention is that it provides a more rigid carbide backing for greater strength as the carbide stud is continuous with no braze interruption. Another advantage of the present invention over the prior art is multiple transition layers of varying percentages of diamond and tungsten carbide particles may be directly bonded to a carbide stud surface to provide superior impact strength of the diamond layer and the bond line.

It should also be understood that other ultra-hard materials, such as cubic boron nitride particles, may be used in lieu of diamond particles to form the ultra-hard cutting layers of all the above embodiments.

For certain applications or cutter geometries, it may be advantageous to use other means than tape cast processes to bond an ultra-hard material mass to a carbide

substrate surface to form a brazeless cutter. For example, a method may be injection moulding of diamond, cubic boron nitride or other ultra-hard particles admixed with a binder into a mold cavity containing a pre-formed carbide substrate. This assembly is then sintered under high pressure/high temperature conditions to form a brazeless cutter. Another method may be extrusion of a hard particle/binder mass into a pre-form for subsequent high pressure/high temperature sintering to a carbide substrate. Another method may be the placing of loose ultra-hard particles into a mold cavity containing a pre-formed carbide substrate for subsequent high pressure/high temperature sintering to the carbide substrate.

It will, of course, also be realized that various other modifications can be made in the design and operation of the present invention without departing from the spirit thereof. Thus, it should be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

Attention is drawn to the description and claims of co-pending application no. 9418471.0.

CLAIMS

1. An insert stud cutter for rock bits comprising:

a tungsten carbide cylindrical body, said body having a first cylindrical base end and a second cutter end, said second cutter end having at least one layer of ultra-hard material selected from the group consisting of polycrystalline diamond and polycrystalline cubic boron nitride directly bonded to a pre-formed surface on said second cutter end by a high pressure, high temperature sintering process, said pre-formed surface being angled negatively with respect to an axis of said stud body 5° to 30°.

2. An insert stud cutter as set forth in Claim 1 wherein the negative angle is 20°.

3. An insert stud cutter as set forth in either one of Claims 1 or 2 wherein said pre-formed surface is planar.

4. An insert stud cutter as set forth in either one of Claims 1 or 2 wherein said pre-formed surface is curved.

5. An insert stud cutter as set forth in Claim 4 wherein said curved surface is convex.

6. An insert stud cutter as set forth in Claim 4 wherein said pre-formed surface is a truncated cone.

7. An insert stud cutter as set forth in any one of Claims 1 to 6 wherein the stud cutter contains at least one transition layer between the layer of ultra-hard material and the body, the transition layer comprising a mixture of ultra-hard material and tungsten carbide particles.

8. An insert stud cutter as set forth in any one of Claims 1 to 6 wherein said ultra-hard material comprises one or more layers of tape cast material sintered to said pre-formed surface.

9. An insert stud cutter as set forth in Claim 8

wherein application of said tape casting material comprises the steps of:

mixing ultra-hard material with a temporary binder to form a homogeneous mass;

rolling the homogeneous mass into strips of a desired thickness and width;

cutting a shape from such a strip to conform to the body geometry;

temporarily attaching the shape to a body as a green layer;

heating the body and green layer for removing the temporary binder; and

sintering the ultra-hard material to the body in a high temperature/high pressure apparatus.

The Patent Office

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Application No: GB 9702164.6
Claims searched: 1 to 9

Examiner: Karl Whitfield
Date of search: 5 April 1997

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): E1F (FFP, FGA, FGB, FGC)

Int Cl (Ed.6): E21B 10/46, 10/56

Other: Online database: Derwent World Patents Index accessed via Questel

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	GB 2138054 A	(N L INDUSTRIES) see especially figures 3-7	
A	GB 2136035 A	(N L INDUSTRIES) whole document	
A	US 4811801	(SALESKY et al) see especially figures 3, 4, 6 & 7	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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